TDA Progress Report 42-57 March and April 1980

DSN Command System Mark III-80

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DSN Command System configuration and functional operation are described. Voyager and Helios command operations are supported with DSS store-and-forward data handling; Viking and Pioneer are supported with the older, near-real-time data handling method.

I. System Functional Description

End-to-end command system operations are represented functionally in Fig. 1. Command sequences for one or more spacecraft are generated and stored at a Mission Operations Center (MOC). Commands for a particular spacecraft are selected from the command files, formatted into messages, and stored for transmittal to a specified Deep Space Station (DSS). Command data are extracted from the messages received at the DSS and stored until radiated. Finally, the commands arrive at the spacecraft and are either executed immediately, or stored onboard for later execution.

The functions of the DSN Command System in this process include the following:

(1) Establishing the DSS configuration for the specified spacecraft.

(2) Receiving and storing command data at the DSS.

(3) Queuing command data to be radiated to the spacecraft.

(4) Radiating the command data to the spacecraft.

(5) Monitoring and reporting system status and events.

The Network Operations Control Center (NOCC) provides control and monitoring of the DSN Command System. Instructions from NOCC and command data from MOC are communicated to the DSS via the Ground Communication Facility (GCF) High-Speed Data Subsystem (GHS), as shown in Fig. 2.

II. System Configuration

A detailed diagram of the DSN Command System Mark III-80 is presented in Fig. 3. The Mark III-80 system configuration includes provision for uplink frequency control, as described in Ref. 1, via the DSN Tracking System. The Digitally-Controlled Oscillator (DCO) on the exciter assembly receives tuning parameters from the Metric Data Assembly (MDA). Manual operation of the DCO is also provided, for emergency backup. All other features of the Mark III-80 configuration are the same as in the Mark III-78 configuration described in Ref. 2.

During 1978, the DSS Command Processor Assembly (CPA) software program was upgraded to include the "store-and-forward" data-handling method and increased command storage capacity. The JPL Mission Control and Computing Center (MCCC) was reconfigured to provide the required processing functions to utilize the store-and-forward technique for Voyager and Helios spacecraft command operations. The Pioneer and Viking mission operations organizations chose to continue to use the older, near-real-time method of command data handling.

The CPA program (DMC-5084-OP-F; Rev. A) was transferred to operations in November 1978 with several anomalies in the status reporting functions of the store-and-forward portion of the software. A new version of the program (DMC-5084-OP-G) was developed during 1979 and was transferred to operations in April 1980, after extensive acceptance tests showed that the major anomalies were corrected. This program version is to become operational in early May after the Voyager Project Ground Data System (GDS) organization completes MCCC interface tests with the various Deep Space Stations.

Some minor anomalies, related to local DSS displays, were identified in testing of the OP-G version of CPA software. Correction of those anomalies is planned in a program upgrade to be implemented in early 1981. The upgrade is also intended to expand the store-and-forward capability to multimission applicability for support of future missions.

III. Pretrack System Preparation

DSS pretrack operations performed by station personnel include initializing the CPA software for "phase 1" for "phase 2" operation so that the CPA will be prepared to recognize the content of the high-speed data blocks to be received from NOCC and the flight project command center. Phase 1 initialization is required for the older type (Mark III-74) command data messages; phase 2 initialization is required for the new (Mark III-78, store-and-forward) type. Additional on-site initialization inputs to the CPA specify the flight project name and the spacecraft identification number. These inputs cause the software to transfer a specific configuration and standards and limits table from disk storage to memory, and to configure the Command Modulator Assembly (CMA) and CPA according to the table. Changes may later be made by high-speed data messages from NOCC or by keyboard entries at the Data System Terminal (DST) in the station.

Upon initialization, the CPA sends DSS Command Subsystem (DCD) configuration and status information across the star switch controller (SSC) to the DSS Monitor and Control Subsystem (Fig. 4) for inclusion in the monitor data blocks that are periodically transmitted to the NOCC to provide station status displays in the Network Operations Control Area (NOCA). The subsystem configuration and status information are also sent from the CPA to the DST for station display.

Prior to the beginning of the scheduled spacecraft track, the control of the station command functions is transferred to the NOCC. Configuration and standards and limits are updated by transmission of high-speed data messages from the NOCC Command Subsystem (NCD) real-time monitor (RTM) processor. The configuration and standards and limits are derived from files maintained in the Network Support Computer (NSC). Spacecraft-dependent parameters, such as symbol period, subcarrier frequency, alarm limits, and abort limits, are established via these messages. After the proper configuration and standards and limits have been established, test commands are transmitted through the system to ensure that the system can accept spacecraft commands via high-speed data messages, temporarily store the commands, and confirm radiation. After NOCC operations personnel have established that the system is operating properly, the system control is transferred to the flight project's MOC for transmission of actual spacecraft command sequences during the spacecraft track period.

At the time for radiation of each command element, the CPA establishes the proper mode (see Fig. 5 for description of the various modes) and configuration of the CMA; then the command is transferred to the CMA for immediate radiation via the Receiver-Exciter, Transmitter, Microwave, and Antenna Subsystems.

IV. Command Data Handling

A. Phase 1 Method: Near-Real-Time

With the CPA initialized for phase 1 operation, the data handling method is functionally the same as has been used since 1973. A command stack provides storage of up to four high-speed data blocks (stack modules) of command data. Each block may contain up to six command elements. Each command element consists of up to 71 bits of command data and, at project option, can be either timed or nontimed. Since the phase 1 storage is small, the MOC may need to update the CPA command stack frequently during a DSS spacecraft track.

The top command element in the first stack module is eligible for radiation to the spacecraft. Nontimed commands are radiated immediately after eligibility. Timed commands are radiated after becoming eligible at the time specified in the high-speed data block.

During command operations, events may occur in which high-speed data message transmission to the NOCC and MOC becomes necessary. The following events initiate message transmission:

(1) Acknowledged receipt of a high-speed data block.

(2) High-speed data block rejected by the CPA.

(3) DSS alarm or alarm clear.

(4) Response to a recall request.

(5) Confirmed command element.

(6) Aborted command element.

B. Phase 2 Method: Store-and-Forward

The store-and-forward data-handling method associated with phase 2 initialization of the CPA utilizes the CPA disk to provide expanded storage of command data. This method is designed to allow mission operations to prepare large files of spacecraft commands in advance and then to forward several files to the DSS at the beginning of a DSS spacecraft track.

1. Command files. Each file may consist of 2 to 256 high-speed data blocks. The content of each data block is a file *element*. The first block in a file contains the *header element* and each remaining block contains a *command element*. Each command element may consist of up to 800 bits of spacecraft command data. Up to 8 files for a given mission can be stored by the CPA. Thus, the available storage is over 1.6 million command bits.

The header element contains file identification information, file processing instructions, and a file checksum for error protection. Once generated (normally by project command generation software), the information is unchanged throughout the ground system. The file processing instructions include optional file radiation open and close window times, and an optional file bit 1 radiation time. File open and close window times specify the time interval during which command elements in the file may begin radiation (i.e., a mission sequence may demand that specific commands *not* be sent before or after a certain time). The bit 1 radiation time allows the project to specify the exact time at which the file is to begin radiation to the spacecraft. The file checksum is intended to provide error protection for the end-to-end ground command system. It is created at the time of file generation and is passed intact to the DSS. It adds reliability to insure that no data were dropped or altered in the transfer from one facility to another.

The command elements each contain command bits, file identification information, element number, element size, and an optional "delay time" (interval from start of previous element). If delay time is not specified, the element will start radiating immediately after the end of the previous element.

2. Receiving and storing command data at a DSS. Normally, the files of commands to be radiated to the spacecraft are sent to a DSS at the beginning of a spacecraft track period. The first step in receiving and storing command data at a DSS is the process of opening a file area on the CPA disk at a DSS. The MOC accomplishes this by sending a header element, which serves as a *file-open* directive. After the CPA acknowledges receipt of the header element, the MOC sends the remainder of the file (up to 255 command elements) and follows it with a *file-close* directive. The CPA acknowledges the file-close instruction and indicates whether the file loading was successful or unsuccessful. If the file loading was unsuccessful, the acknowledge message contains the reason for the failure, and from what point in the file the command elements are to be retransmitted. When the file is successfully closed, the MOC may proceed to send additional files, up to a total of eight.

3. Queuing the command data for radiation. After the files are stored at the CPA, the MOC sends one or more file-attach directives to place up to five file names in the radiation *queue*. The Mission Control Team determines in which order the files are to be attached. The order in which they are attached determines the sequence in which they will be radiated: that is, first attached, first to radiate to the spacecraft.

4. Command radiation to the spacecraft. The first command element in the top (prime) file in the queue begins radiation to the spacecraft immediately after attachment or as soon as all optional file instructions are satisfied. The prime file status is defined to be active when the first command element begins radiation. Upon completion of radiation of the first command element, the second command element begins radiation either immediately or when the optional delay time has been satisfied. The process continues until all command elements in the file have been radiated. After the first file completes radiation, the second file in the queue automatically becomes the prime file and the command radiation process is repeated. After the second file completes radiation, the third file becomes prime, etc. This process is repeated until all files in the queue are exhausted. The MOC can attach new files to the queue whenever space is available.

Confirmations of command element radiation are reported in *event messages* to the MOC and NOCC once per minute, or after five elements have been radiated, whichever occurs first. If a command element is aborted, an event message is sent immediately.

5. Additional data processing. The foregoing descriptions of the functions of storing the command files at a DSS, attaching the files to the queue, and radiating the commands to the spacecraft assume nominal-standard operation. Additional data processing functions are provided for worst-case conditions, nonnominal operations, and failure recovery.

a. File erase. The capability exists to delete a file from storage at the CPA. This *erase* function can be accomplished either locally at a DSS or via a high-speed data message from the MOC.

b. Clearing the queue. As previously stated, the order of file radiation to the spacecraft is dependent on the order of files in the queue. To rearrange the order, the MOC must send a *clear-queue* directive, followed by file-attach directives in the desired order.

c. Suspend radiation. If the Mission Control Team desires to stop command radiation, a *suspend* message can be sent from the MOC. This message stops command radiation to the spacecraft upon completion of the current element. The file status then changes from active to suspended.

d. Resume command radiation. To restart radiation of a suspended file (either suspended intentionally or from an abort), a message can be sent from MOC to *resume* radiation *at* a specific element in the file.

e. Command abort. As each command bit is radiated to the spacecraft, numerous checks are made to insure validity of the command data. If a failure is detected during radiation, the command element is *aborted*, and the prime file status is changed from active to suspended. Optional methods of treating an abort are provided. If one or more automatic recovery attempts have been specified in the standards and limits, the CPA will try to resend the command element, or else radiation will be terminated until operator intervention occurs.

f. Close window time override. The close window time (previously discussed) can cause an actively radiating file to become suspended. If this occurs, the MOC can send an *override* message that directs the CPA to ignore the close window time and proceed to radiate the complete file.

V. Data Records

All high-speed data blocks received by the CPA and all high-speed data blocks sent from the CPA are logged at the DSS on the Original Data Record (ODR) by the Communications Monitor and Formatter (CMF). The CPA has the capability to record a temporary ODR on disk, if the CMF ODR is disabled.

High-speed data blocks from all DSS are recorded at the GCF central communications terminal (CCT). Command system high-speed data blocks from a Mission Operations Center to the DSS are also recorded at the CCT.

The DSS original data records and the CCT recordings provide information for fault isolation in case problems occur in the command system operation.

References

1. Spradlin, G. L., "DSN Tracking System Uplink Frequency Control," in *The Deep Space Network Progress Report 42-53*, pp. 108–112, Jet Propulsion Laboratory, Pasadena, California, October 15, 1979.

2. Thorman, H. C., "DSN Command System Mark III-78," in *The Deep Space Network Progress Report 42-49*, pp. 11–18, Jet Propulsion Laboratory, Pasadena, California, February 15, 1979.

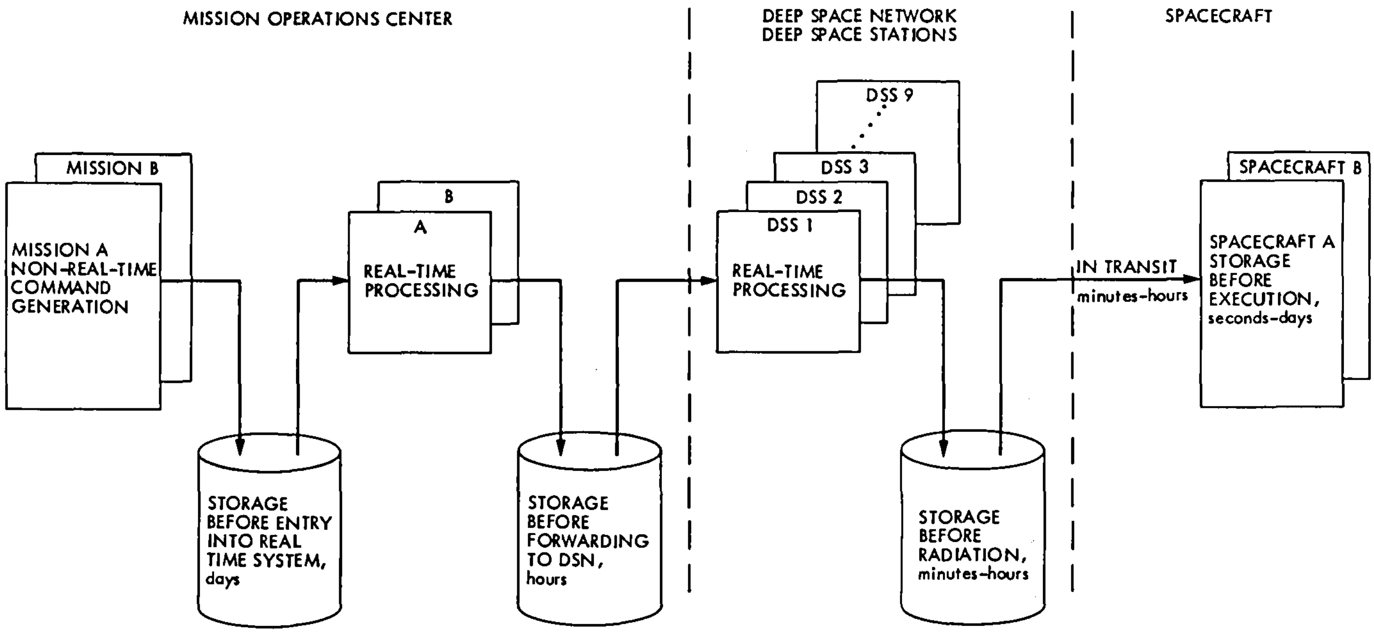


Fig. 1. End-to-end command data flow—typical storage times

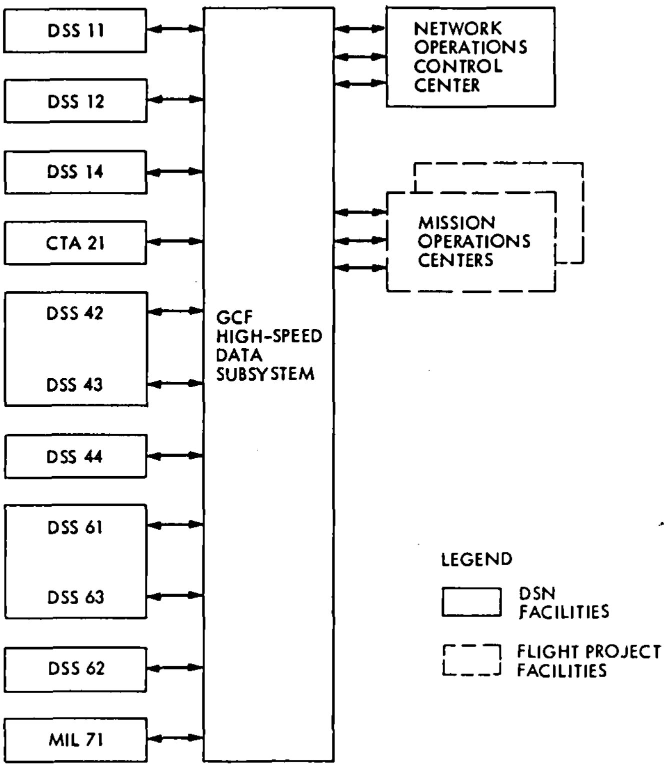


Fig. 2. Facilities that participate in command operations

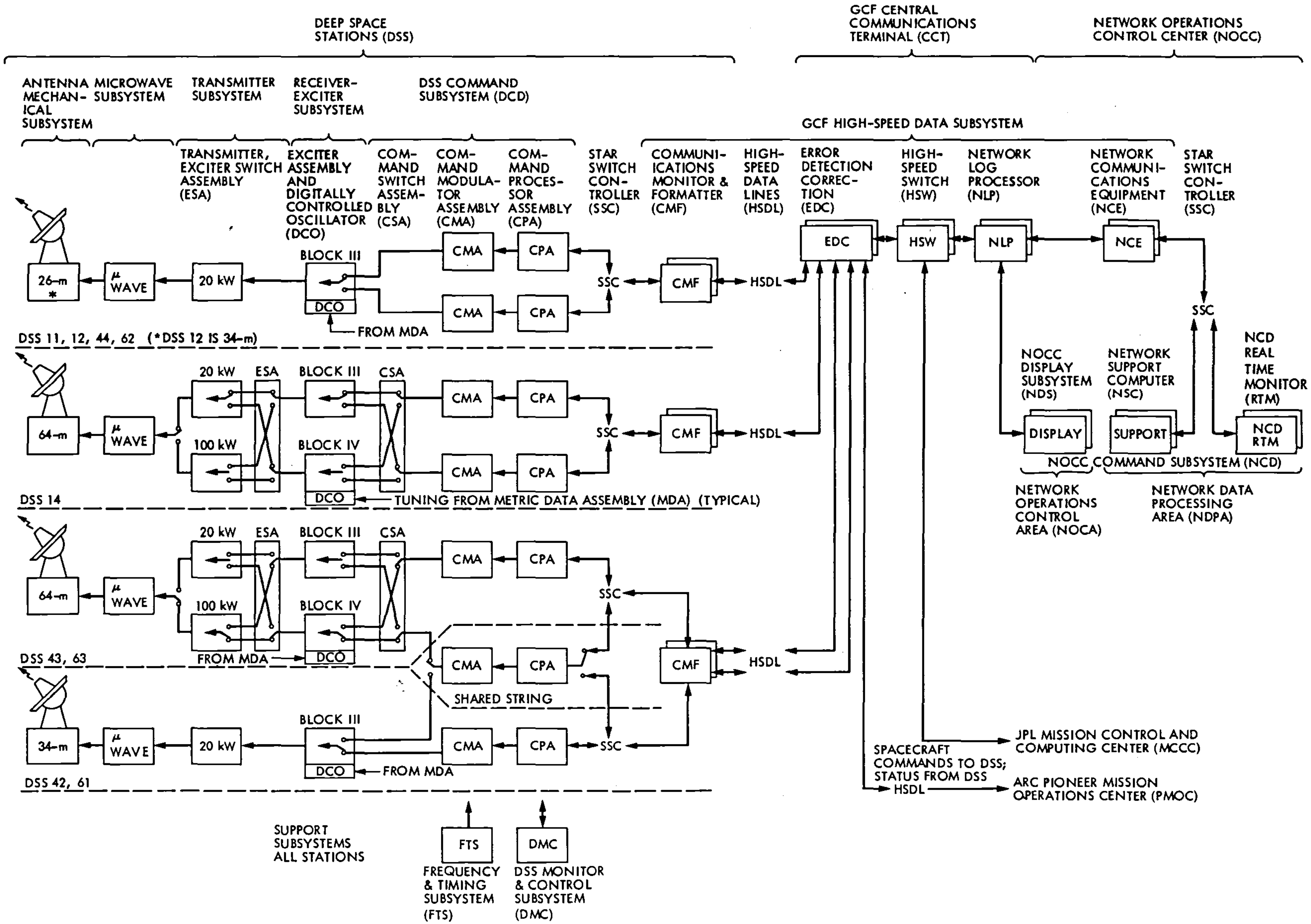


Fig. 3. DSN Command System Mark III-80

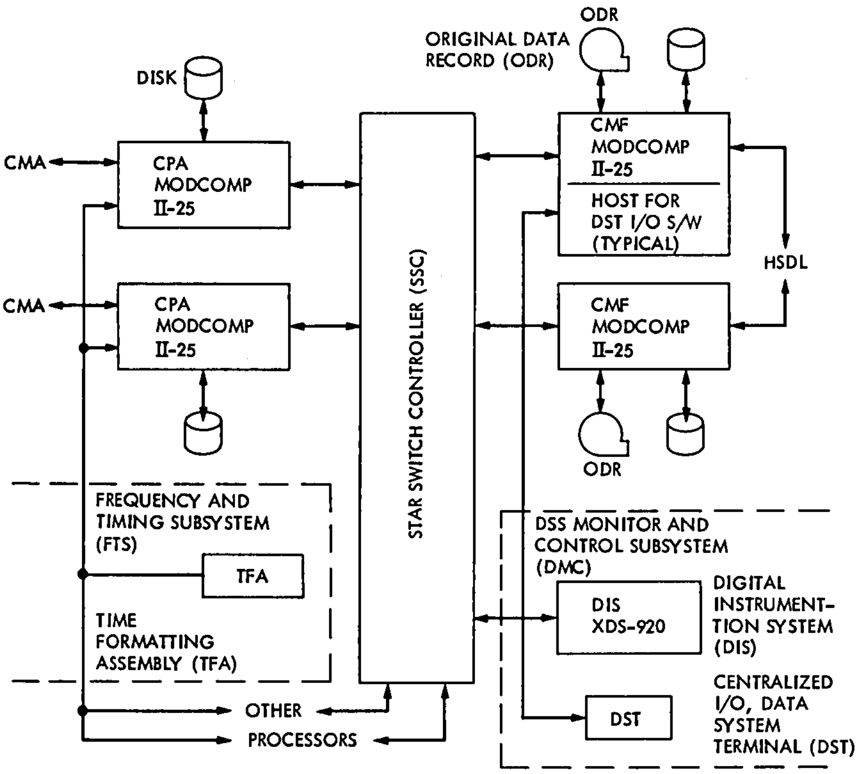
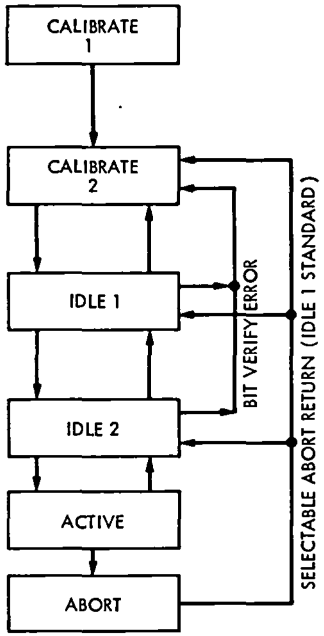


Fig. 4. Deep Space Station interface details



SUBSYSTEM MODE	PRIME PURPOSE	DATA ACCEPTED VIA HIGH SPEED	COMMENTS
CALIBRATE 1	ALLOWS DSS OPS PERSONNEL TO PERFORM INITIALIZATION TASKS	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	UPON RECEIPT OF A STANDARDS AND LIMITS AND CONFIGURATION HSD BLOCK, THE CALIBRATE 2 MODE WILL BE ENTERED
CALIBRATE 2	STANDARD MODE FOR UPDATING STANDARDS AND LIMITS AND CONFIGURATION DATA VIA HIGH SPEED PRIOR TO SPACECRAFT ACQUISITION	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	MULTIMISSION STANDARD PROCEDURES SHOULD STATE THAT THIS MODE IS TO BE ENTERED FOR CHANGING SUBCARRIER FREQUENCY, BIT RATE
IDLE 1	SAFE MODE - CANNOT COMMAND. PROVISION FOR IDLE/ACQUISITION SEQUENCE. ALLOWS CONFIGURATION AND STANDARDS AND LIMITS TO BE CHANGED	CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL	ALL STANDARDS AND LIMITS AND CONFIGURATION DATA PARAMETERS WILL TAKE IMMEDIATE EFFECT IN THIS MODE
IDLE 2	ALLOWS ENTRY INTO ACTIVE MODE. PROVIDES IDLE/ACQUISITION SEQUENCE DURING COMMAND PERIODS	RECALL AND MODE CONTROL DATA ONLY	MODE CONTROL DATA CONTAINED IN THE COMMAND ELEMENT BLOCK
ACTIVE	COMMAND TRANSMISSION	RECALL AND MODE CONTROL DATA ONLY	
ABORT	PROVIDES ABORT INSTRUCTION TO CMA	RECALL AND MODE CONTROL DATA ONLY	

NOTES: 1. COMMAND DATA MESSAGES WILL BE ACCEPTED IN ALL MODES
2. ALARM MESSAGES/ALARM DATA WILL BE TRANSMITTED TO THE MOC IN ALL MODES EXCEPT ABORT

Fig. 5. DSS Command Subsystem modes